Advanced Life Support Considerations

Biological Effects of Dust Workshop

Radisson Inn

Sunnyvale, CA

March 28th -30th, 2005

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Contents

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International Space Station

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AS of 2/01/03

Progress Module

Atmosphere and User Gas Bottles

Airlock

Metal Oxide

Service Module

Functional Cargo Module (FGB)

Node 1

Laboratory Module

DC1

Soyuz

PMA3 on Node 1 Port (Not shown)

Carbon Dioxide Removal

Trace Contaminant Control

Oxygen Generation

Major Constituent Analyzer

Water Storage

Water Processing (PwPotable; HwHygiene)

Personal Hygiene Facility

Galley

Nitrogen Storage

Oxygen Storage

O2 Compressor

Air Save Compressor

LEGEND

Pressure Control Assembly

Primary Temperature and Humidity Control

Vacuum System

Miscellaneous Equip: Fans, Valves, Filters, Smoke Detectors, Portable Fire Extinguishers

ISS Atmospheric Particulate Removal

The International Space Station uses high efficiency particulate air (HEPA) filters.

There are 13 elements deployed on board the ISS US Segment.

The service life prediction for these filters is 2 years.

ISS Design

- Particles are composed of:
  - ❑Skin Flakes - 40%
  - ❑Fibers from clothing- 37%
  - ❑Hair - 15%
  - ❑Paper
  - ❑Aerosols and fluids
  - ❑Organic and inorganic particles
- Agglomeration and dust mites convert small particles into larger particles.

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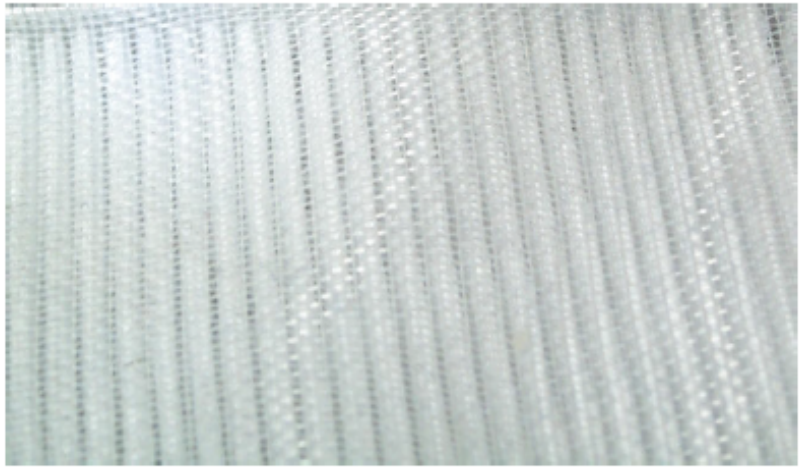
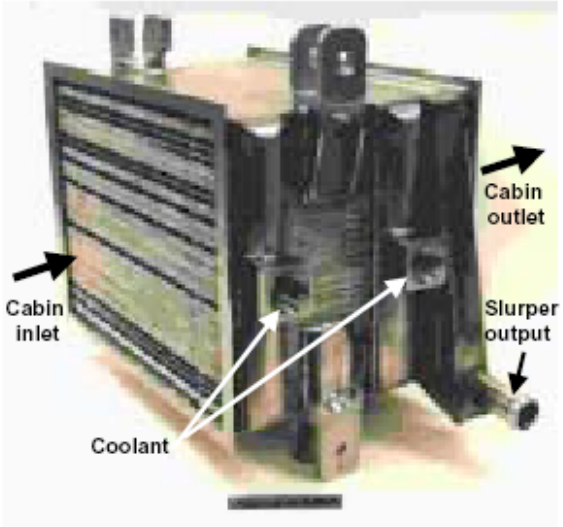
ISS High Efficiency Particulate Air (HEPA) Filters





ISS Design

- HEPA filter provides 99.97% particle removal efficiency at 85 - 150 m^3/hr (50-90 cfm).
- The ISS system is designed to maintain airborne particulate matter to no more than 0.05 mg/m^3 for particulate sizes ranging from 0.5 μm to 100μm.
- Periodic peaks to 1.0 mg/m^3 are allowed.
- This specification is the same as that of Federal Standard 209, Revision E for a class 100,000 clean room.

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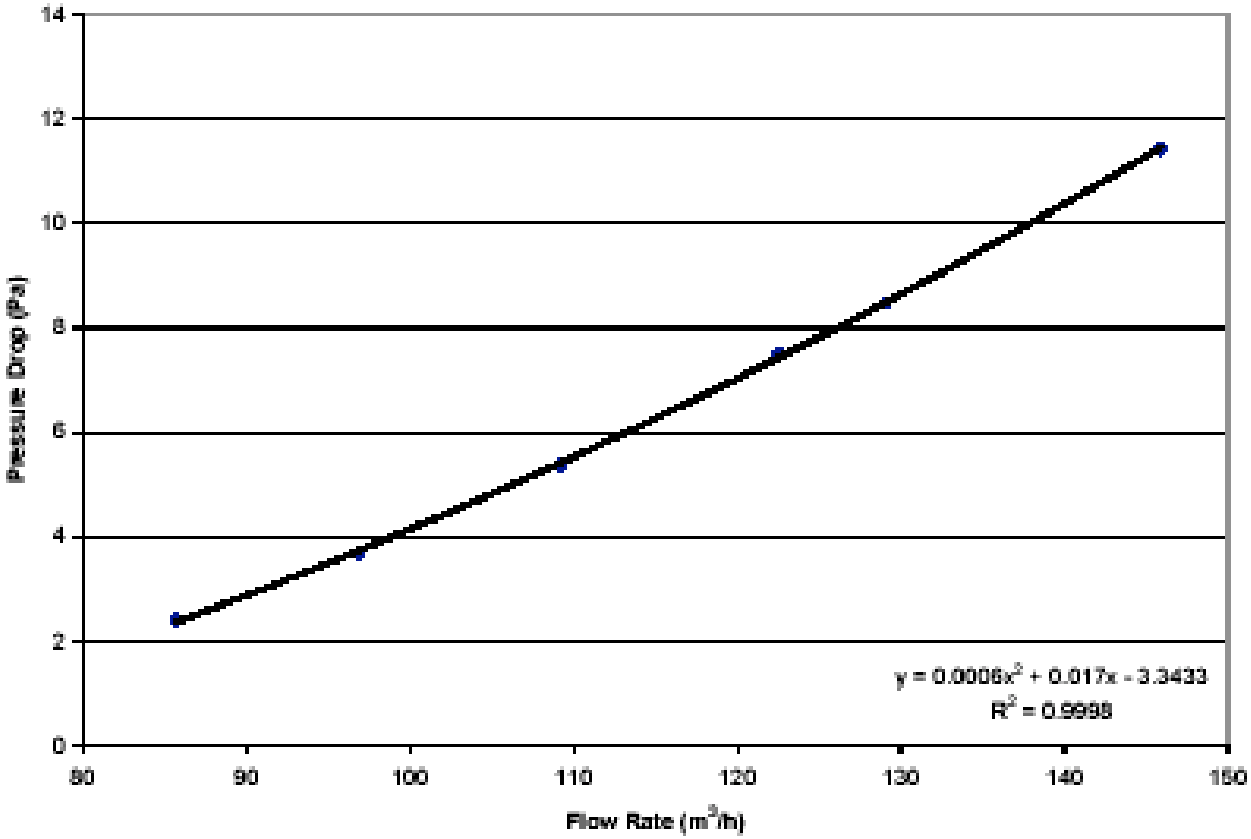
Power Consumption



Re-supply

- ISS HEPA filter resupply requirements are 26 kg/yr.
- This is 13% of ECLS average yearly resupply requirement.

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Problems

Particle contamination of Node 1 optical fire sensor.

Sensor is located upstream of HEPA filters.

In-flight cleaning procedure developed to resolve issue.

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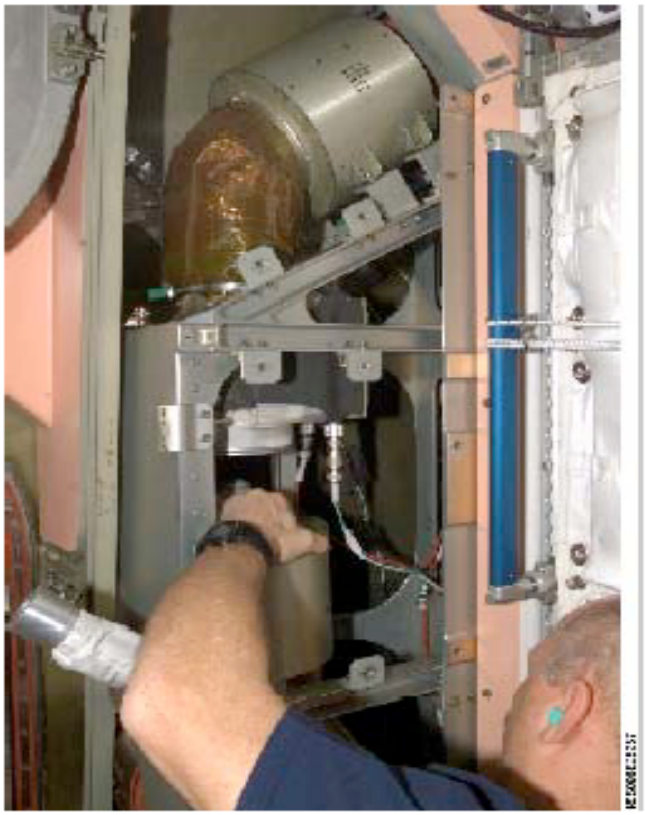
Problems

Testing of US/Russian intermodal ventilation system in CY 03 indicated low flow.

Inspection of ducting by Expedition 6 crew resulted in the removal of a material from the IMV fan flow straighter.

This material was affectionately known as the “lint woolly”.



Removal of lint wooly from IMV fan flow straightners

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ISS Design Issues

- Air circulation rates are defined by gas mixing and dead volume issues not particulate removal.
- The ISS requirements are approximately 4 times lower than the maximum recommended to maintain crew health.
- The level required to maintain crew health was defined by a NASA panel of experts.

NASA Conference Publication 2499

Airborne Particulate Matter in Spacecraft

Proceedings of a panel discussion sponsored by NASA Lyndon B. Johnson Space Center and held at the Lunar and Planetary Institute

Houston, Texas

July **23-24, 1987**

LIST OF PANEL PARTICIPANTS

- **CHAIRMAN**
- Benjamin Y. H. Liu, Ph.D.
- Particle Technology Laboratory
- Mechanical Engineering Department
- University of Minnesota

- **PANEL MEMBERS**
- Harry Ettinger, P.E.
- Los Alamos National Laboratory

- Charles Hobbs, D.V.M.
- Inhalation Toxicology Research
- Lovelace Biomedical and Environmental

•Morton Lippmann, Ph.D.
•Aerosol and Inhalation Research
•Institute of Environmental Medicine

•Dale Lungren, Ph.D.
•Department of Environmental
•University of Florida

•Virgil Marple, Ph.D.
•Mechanical Engineering
•University of Minnesota

•Mark Utell, M.D.
•University of Rochester
•Medical Center

- Objective:
- To review the available information on airborne particles in the Space Shuttle and to recommend acceptability limits and sampling and monitoring strategies both for the Space Shuttle and the Space Station.

- The Panel included:
  - Four aerosol physicists with interests and expertise in lung deposition and health effects.
  - One industrial hygienist.
  - Two medical scientists specializing in toxicology and the health effects of airborne particles.

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Justification

- The Panel was formed in response to reports by Space Shuttle flight crews in the early 1980's.
- These reports included instances of eye and respiratory tract irritation associated with the presence of airborne particles and floating debris in the Shuttle cabin.
- There have also been reported cases of instrument failure caused by airborne particles.
- The Panel was shown debris collected from avionic filters and vacuumed post flight from Shuttle internal surfaces.
- The debris included metal shavings; paint chips; hair; skin flakes; food particles; and glass and fibrous material, including fibers from clothing, Velcro, and fiberglass.

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Panel Recommendations

Panel recommended the following acceptability limits for airborne particles:

a. For flights of 1 week or less duration:

   1 mg/m^3 for particles less than 10 μm in diameter, plus 1 mg/m^3 for particles 10 to 100 μm.

b. For flights greater than 1 week in duration:

   0.2 mg/m^3 for particles less than 10 μm plus 0.2 mg/m^3 for particles 10 to 100 μm

ISS Did Not Incorporate Panel Recommendations

Panel recommendations are based on a population of healthy astronauts engaged in an occupation with a relatively high degree of risk involved.

The 0.05 μg/m3 ISS specification is the level which would protect the most sensitive individuals in the population from continuous, long-term exposure.

Technology selection and mixing requirements drive specifications.

Other Panel Recommendations

- Sampling of spacecraft atmospheres for particles should include size-fractionated samples of 0-10,10-100, and > 100 μm particles for mass concentration measurement.

- Elementary chemical analysis by non-destructive analysis techniques should be completed.

- Morphological and chemical analysis of single particles should also be made to aid in identifying airborne particulate sources.

Panel Recommendations

The Panel also recommended that research be carried out in space in the areas of health effects and particle characterization.

Specific research recommendations included:

(1) lung function measurement.
(2) regional deposition of particles in the respiratory tract.
(3) characterization of aerosols and gases in the space environment and particle generation, transport, and deposition studies.

Implications for Lunar Missions

- Lunar EVAs will result in increased particulate loading.
- The air revitalization system should be able to handle increased loadings.
- Reasonable specifications should be developed.
- New technologies can reduce costs.

New Technologies

- Inertial collection and preconcetration (cyclones and virtual impactors)
- Electrostatic precipitation and filtration
- Magnetically assisted filtration

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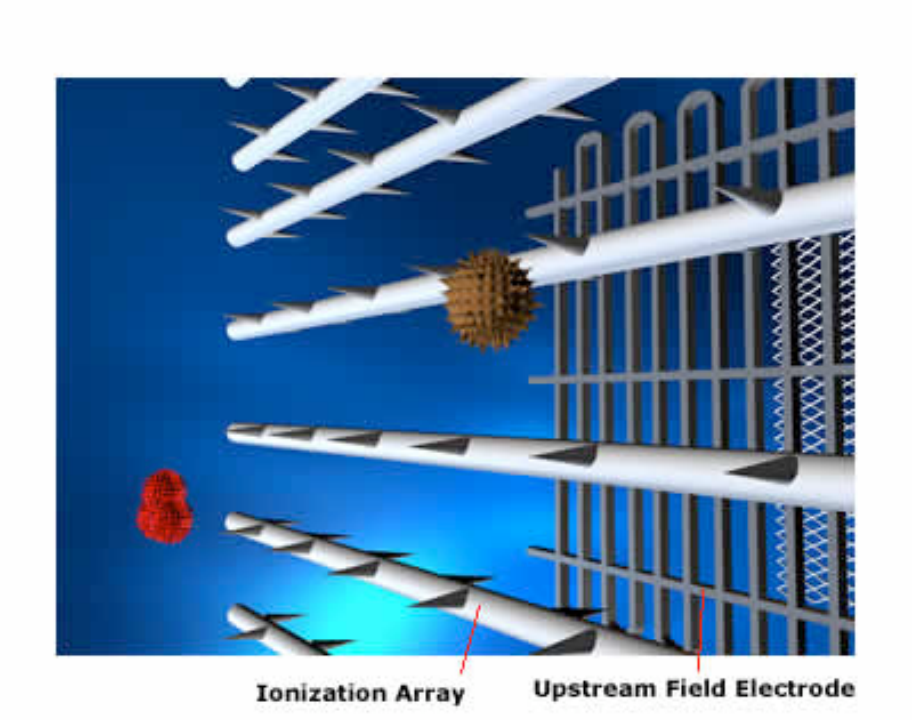
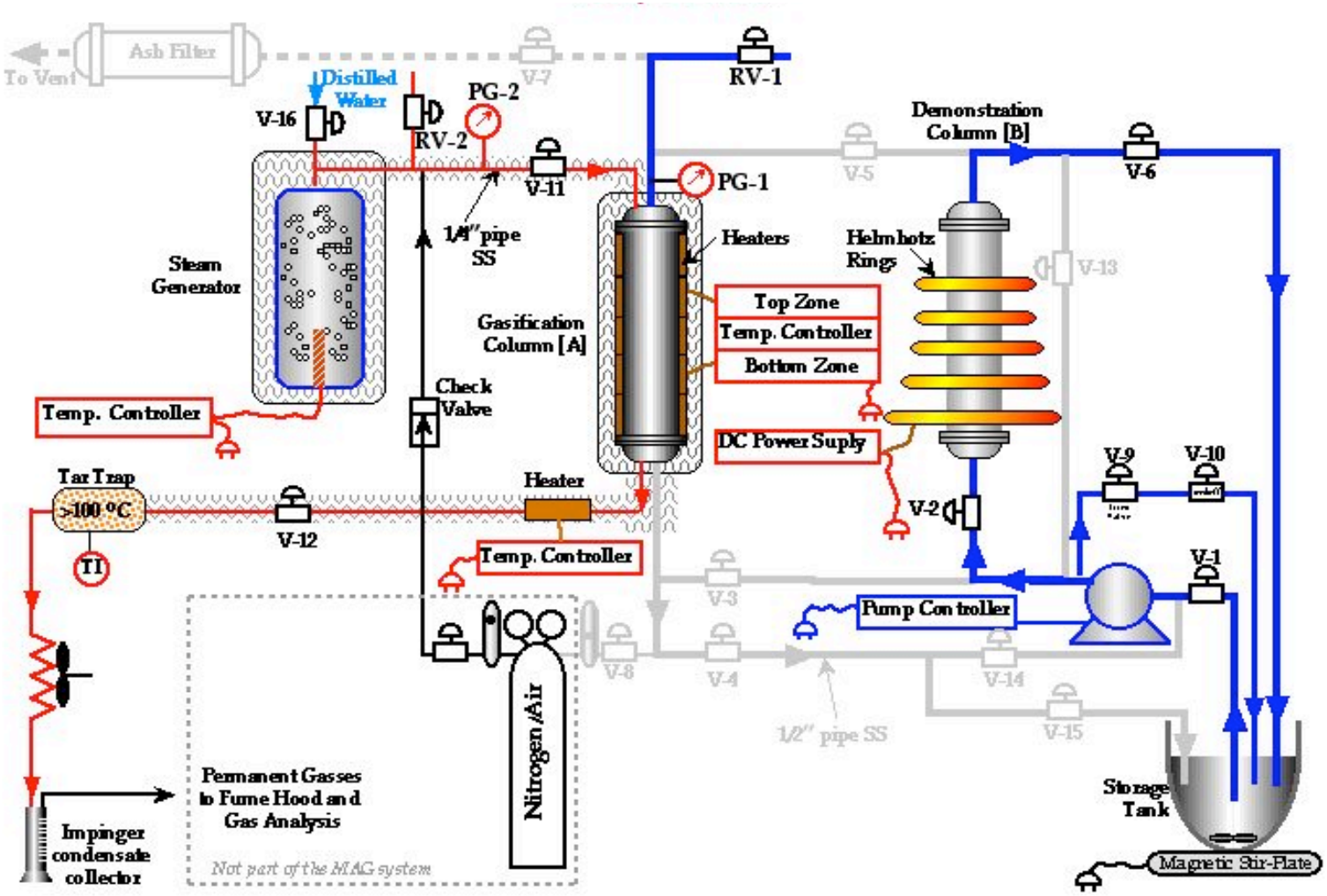
Electrostatic Filtration



Magnetic Filtration



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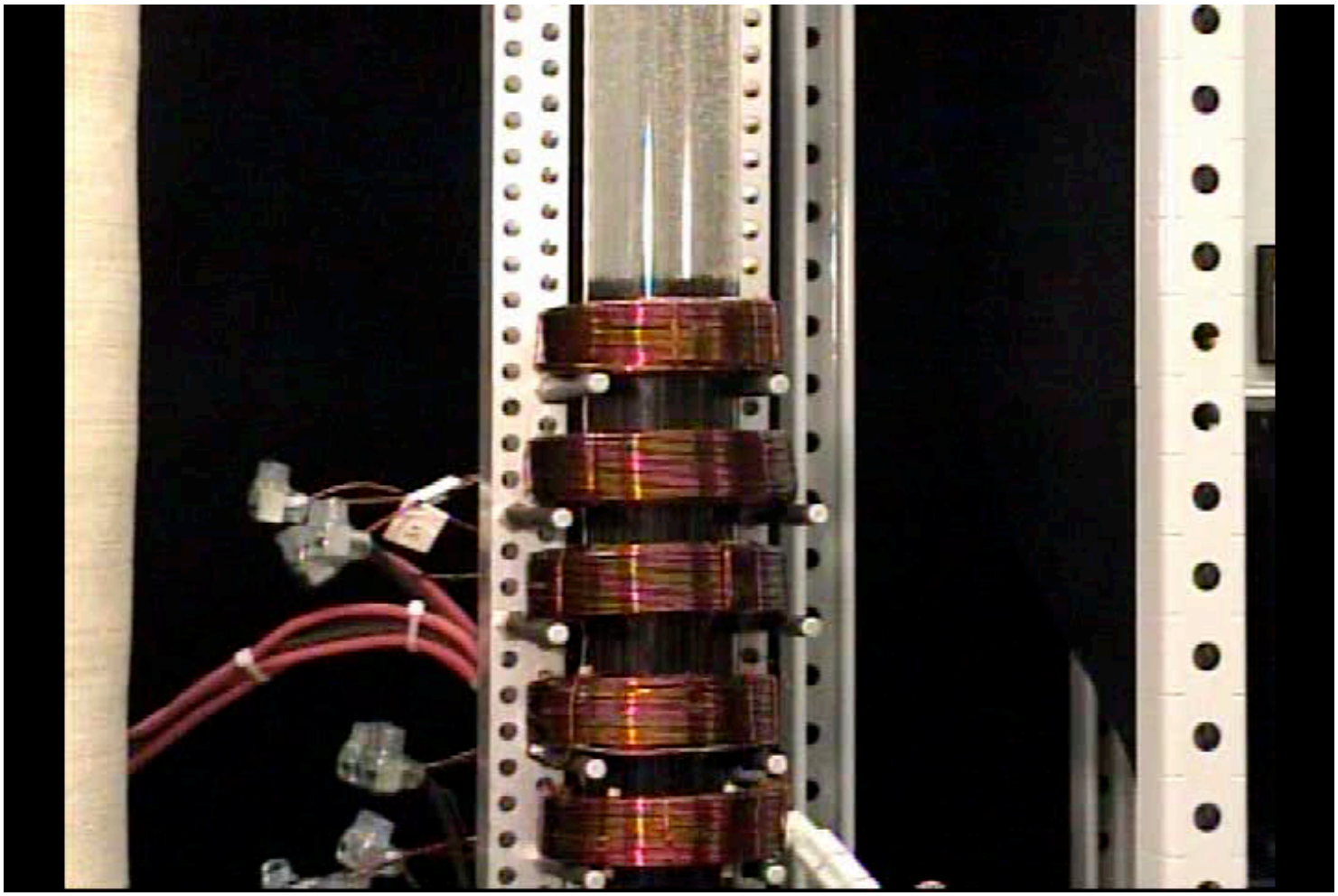
Magnetic Filtration



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Magnetic Filtration

Conclusions

- Current NASA ISS specification is undefined for particles under 0.5 μm.
- EVA operations will result in particulate spikes in atmosphere.
- Existing technologies can meet most requirements, but not without penalties.
- Establishing realistic requirements are critical to developing an efficient design.